Los Alamos National Laboratory Engineering and Design Support for Commercial U.S. Electron Accelerator Production of ^{99}Mo

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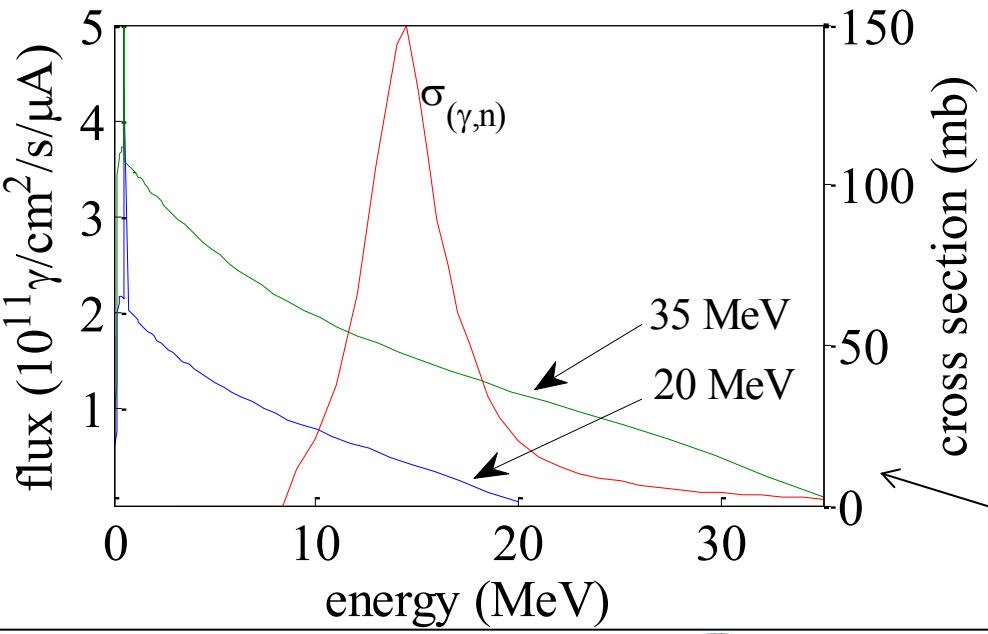
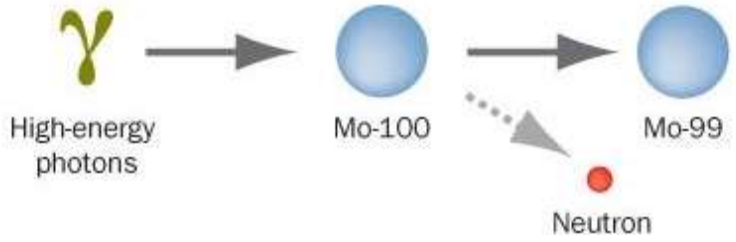
Proof of Concept Demonstrations for Electron Accelerator Production of ^{99}Mo

- **Under the direction of the NNSA, LANL and ANL are partnering with NorthStar Medical Technologies to demonstrate and develop accelerator production of ^{99}Mo through the ^{100}Mo(γ,n)^{99}Mo reaction.**
  - The threshold for the reaction is 9 MeV.
  - The peak cross section is 150 mb at 14.5 MeV.
- **High energy photons are created with a high power electron beam through bremsstrahlung.**





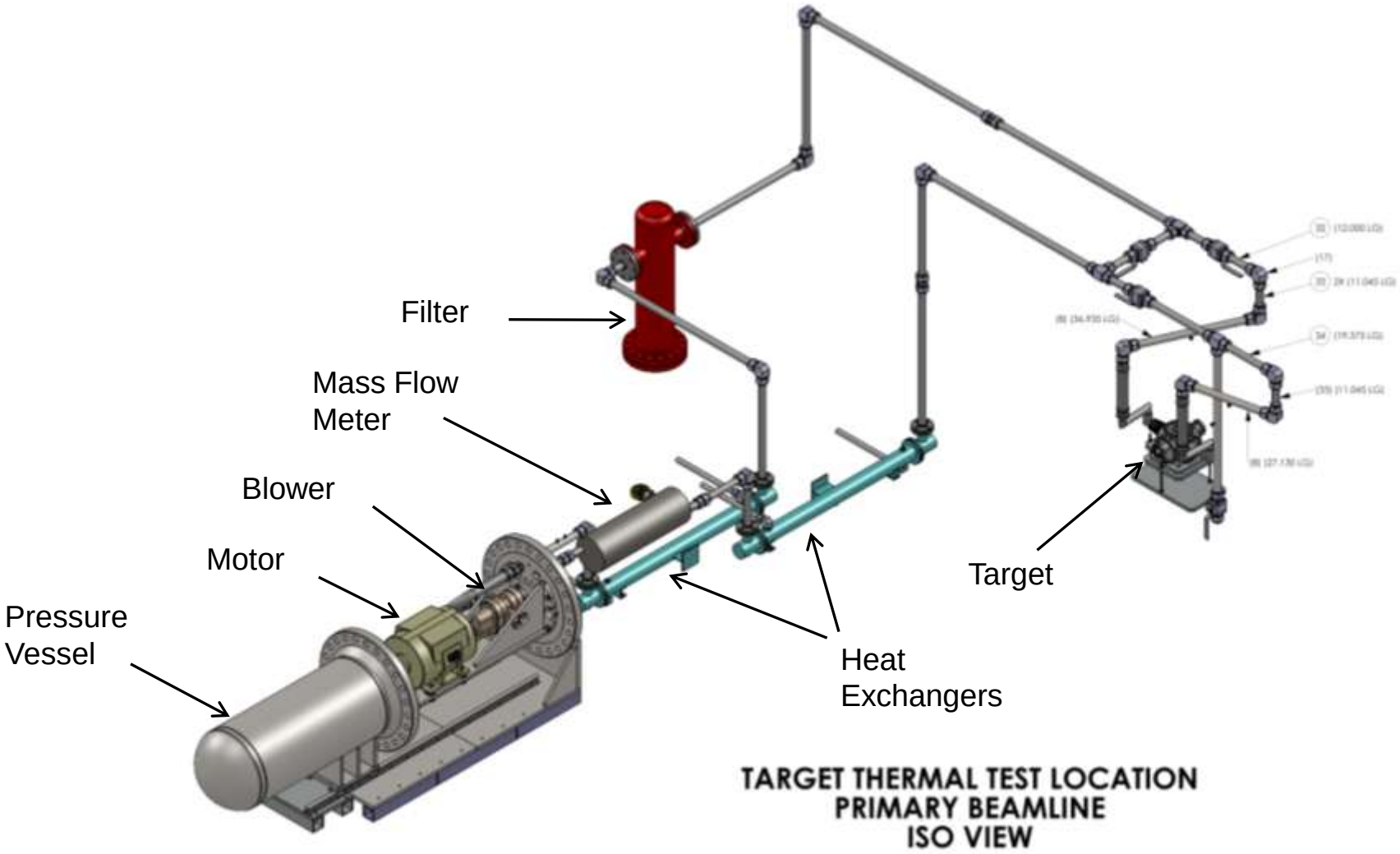
Average bremsstrahlung photon spectra produced with 20- and 35-MeV electron beams in a Mo target compared to the photonuclear cross section of ^{100}Mo.

Scaled Accelerator Tests at Argonne National Laboratory

- **To date, five accelerator tests have been performed using the electron accelerator at ANL.**

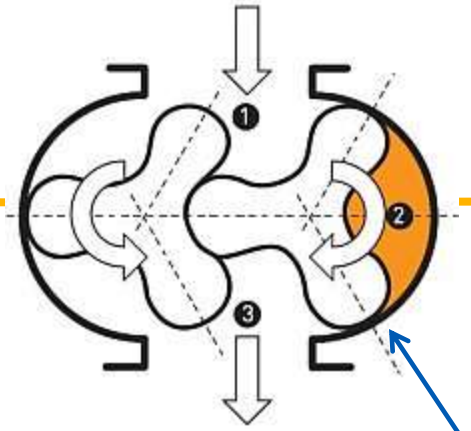
Date	Test
April 2010	Water-cooled target test using natural Mo targets, produced 236 µCi of ^{99}Mo.
May 2010	Water-cooled target test using natural Mo targets, produced 377 µCi of ^{99}Mo.
July 2010	Water-cooled production test using enriched ^{100}Mo targets, produced 10.5 mCi of ^{99}Mo.
April 2011	Once through gaseous helium-cooled thermal test using natural Mo targets, 145 µCi of ^{99}Mo.
March 2012	Closed loop gaseous helium thermal test using natural Mo targets.

Closed Loop Gaseous Helium Cooling System Layout



Gaseous Helium Flow Loop Using a Roots Blower

The roots blower is used to move the He through the loop and across the targets. The PV is used to increase the base pressure of the system to 300 psi.



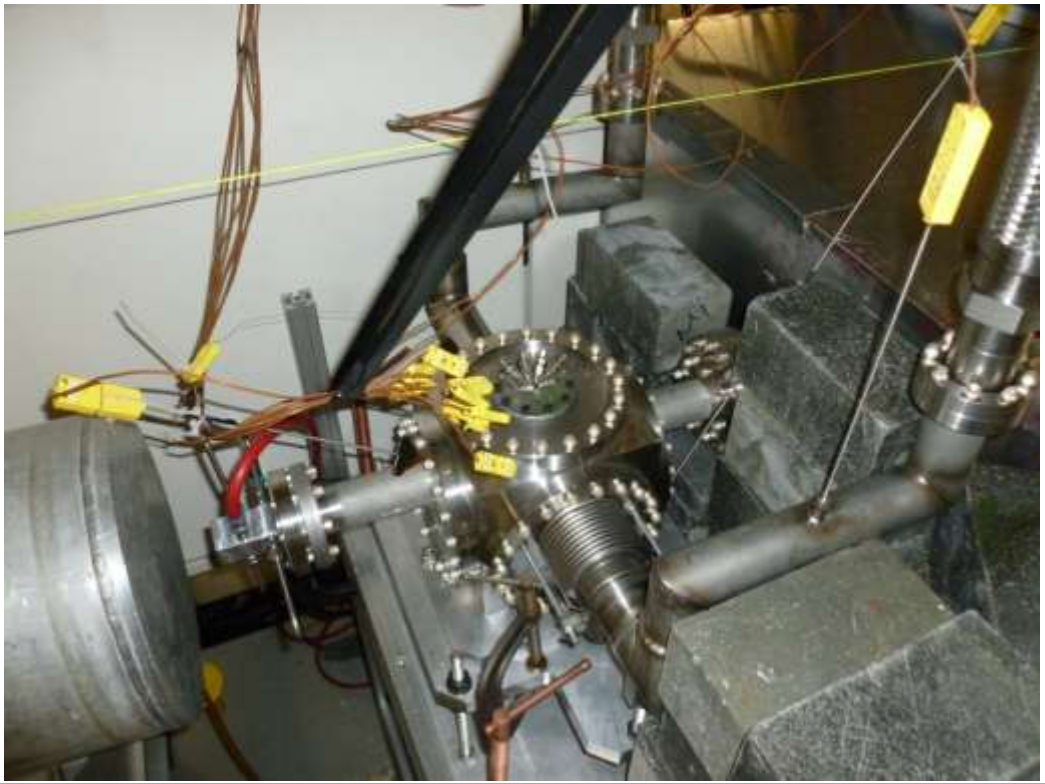
Pressure Vessel (PV)

Electric motor

Roots Blower

Helium Gas Cooled Thermal Test

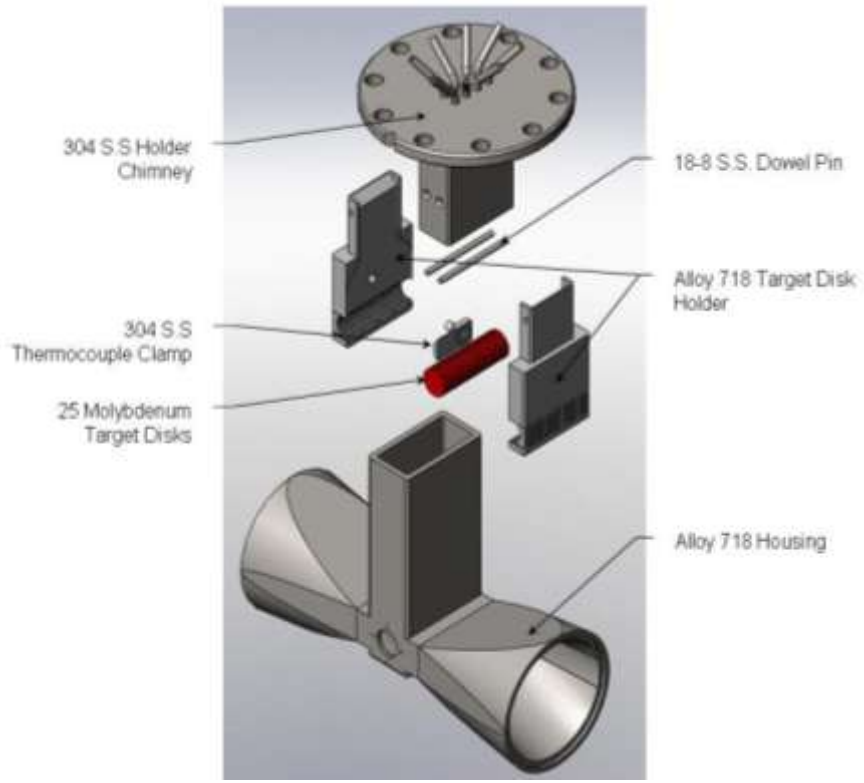
- **Performed on March 27, 2012.**
- **Operated up to a peak beam power of 12 kW at 15 MeV with a 6 mm FWHM beam.**
- **Achieved a production relevant peak heat flux of 819 W/cm^2.**



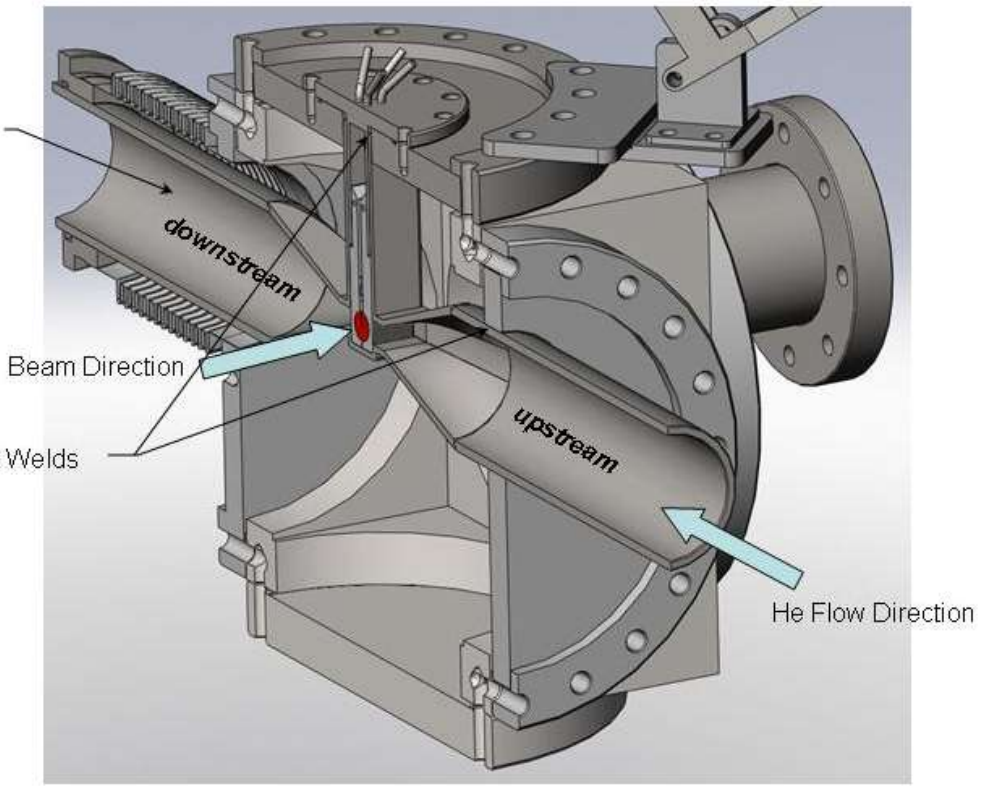
FY12 Target and Vacuum Cube Assembly Design

For the FY12-FY13 accelerator tests, we have integrated the target design into the vacuum system.

Exploded view

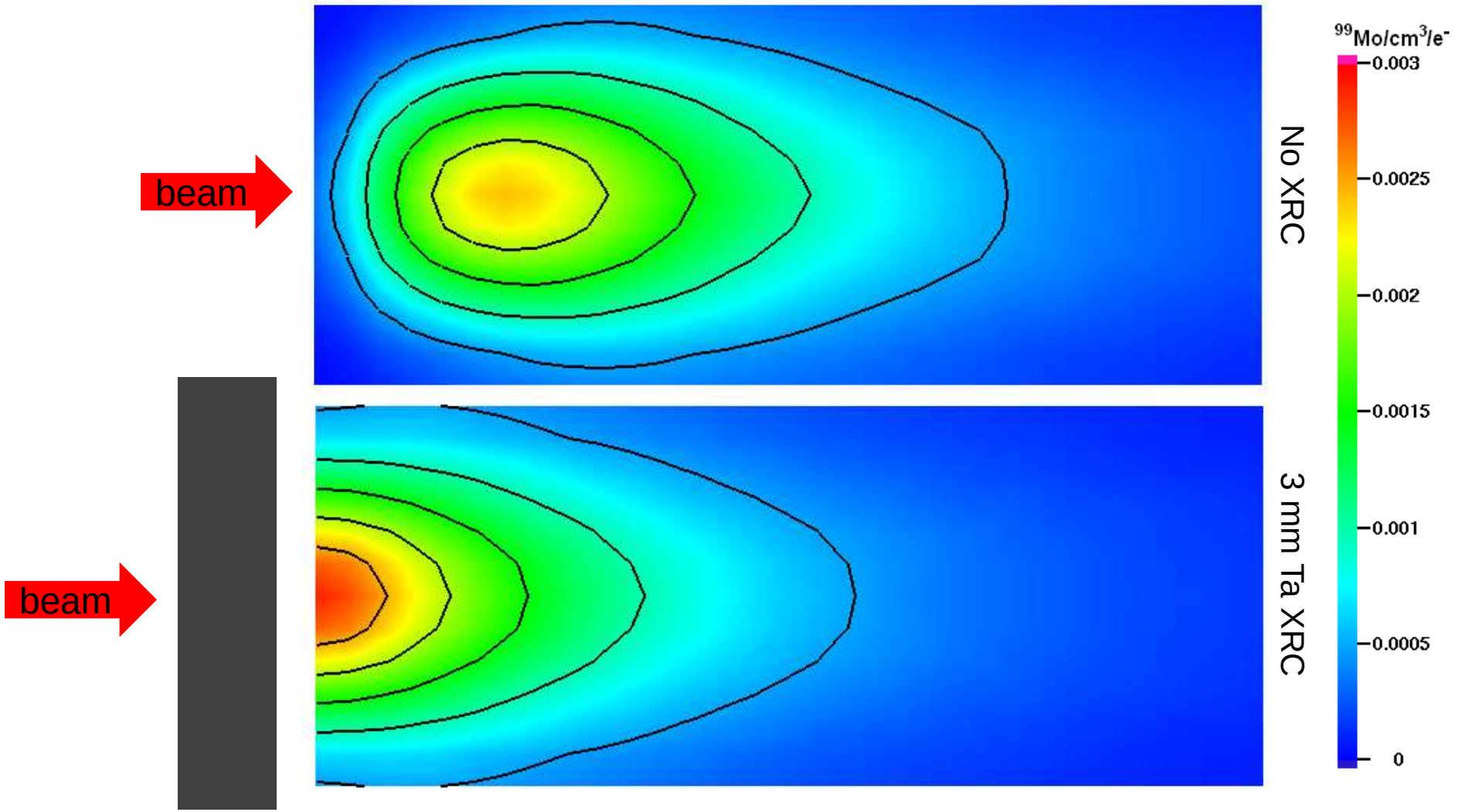


Cut-away view

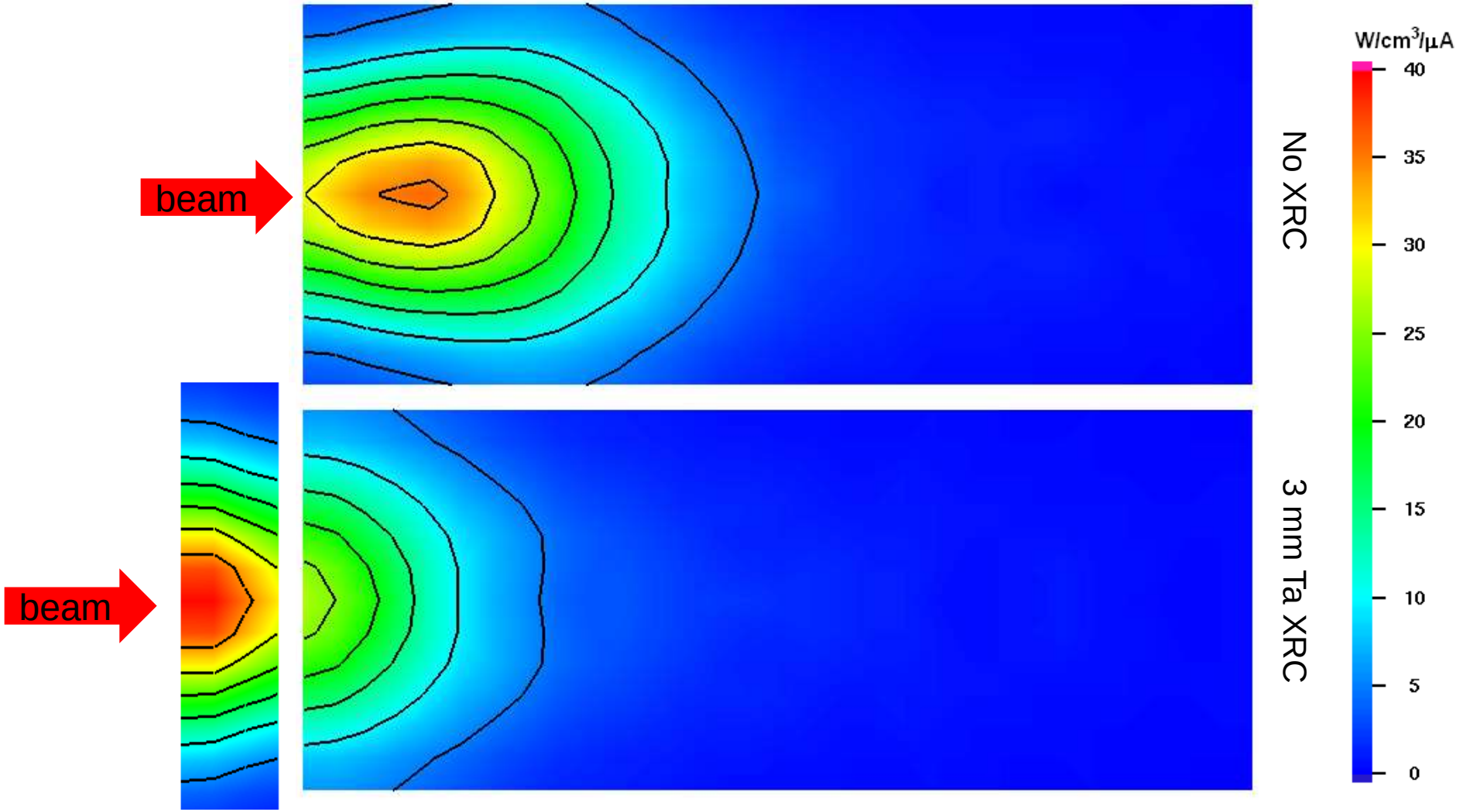


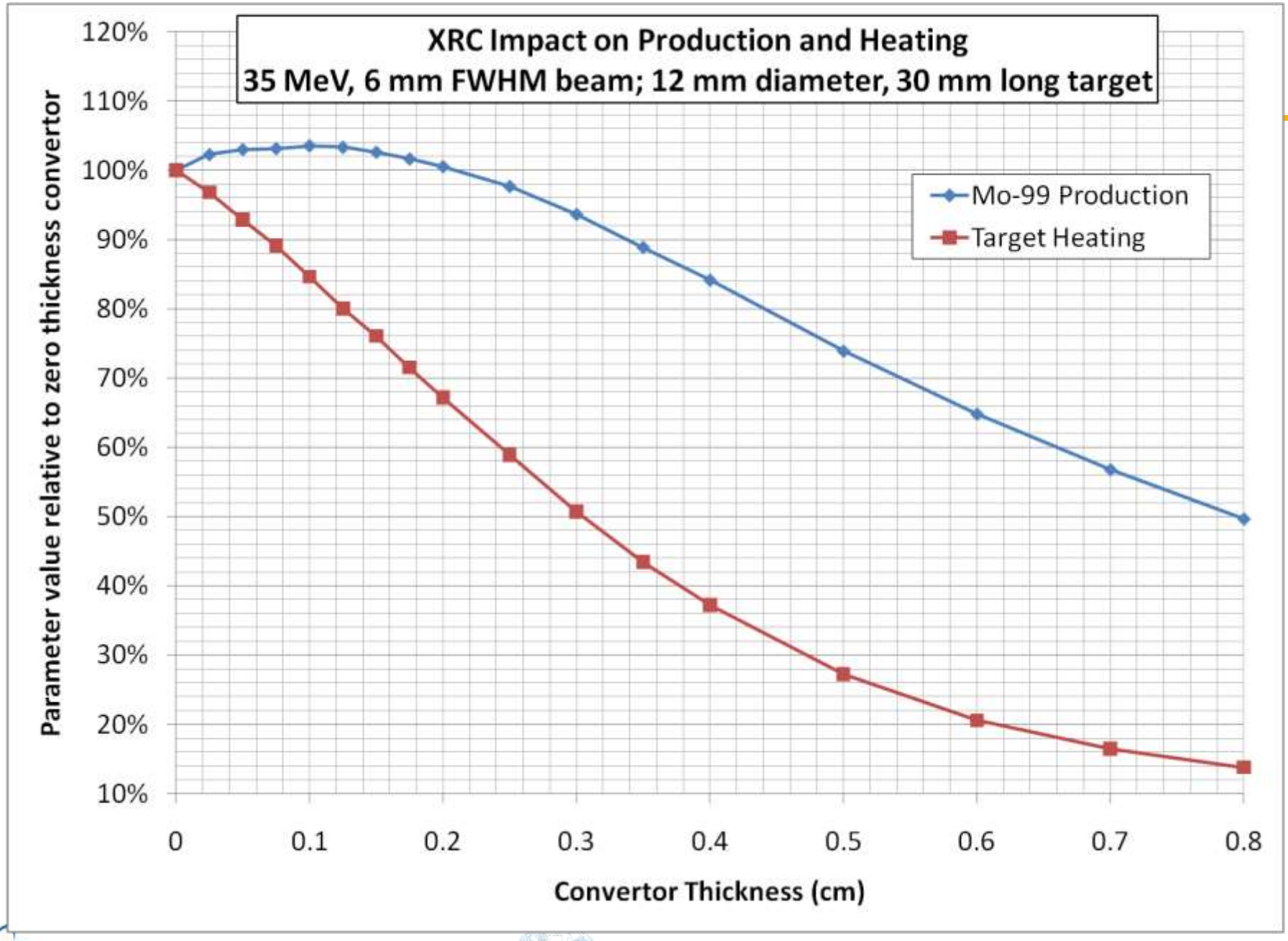
The target is axially symmetric for two-sided irradiation.

^{99}Mo Production Density With and Without an X-Ray Converter. Cylindrical Target, plotted vs. R and Z

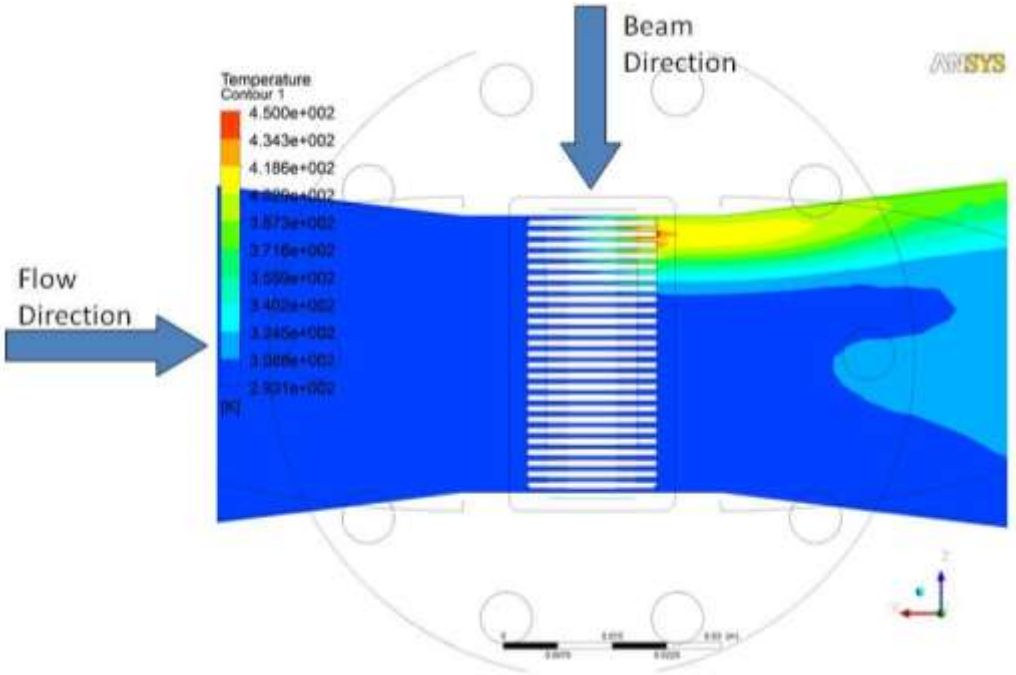


Target Heating With and Without an X-Ray Converter. Cylindrical Target, plotted vs. R and Z



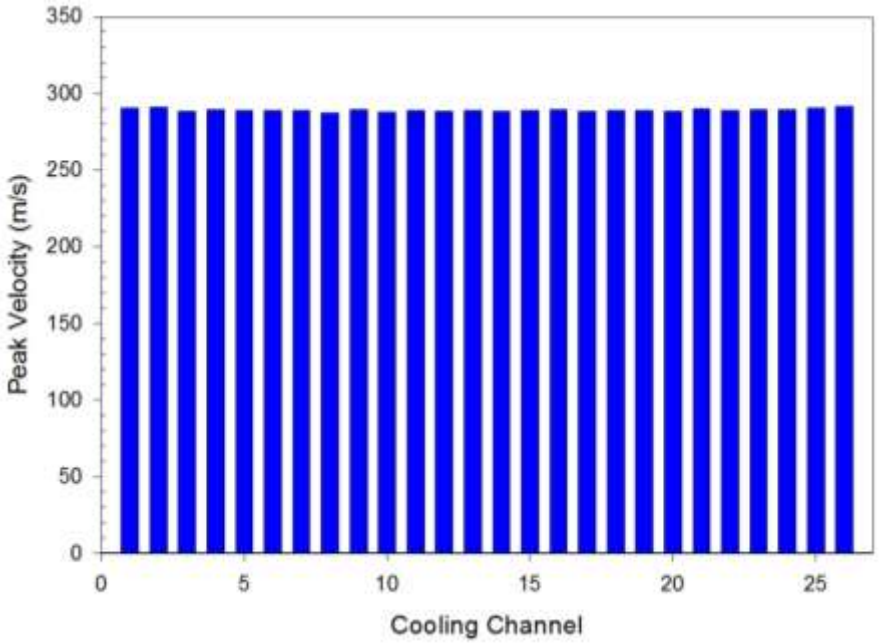

XRC Impact on Production and Heating
35 MeV, 6 mm FWHM beam; 12 mm diameter, 30 mm long target
Parameter value relative to zero thickness convertor
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Convertor Thickness (cm)
Mo-99 Production
Target Heating

CFD Modeling Results of the Target for the Thermal Test

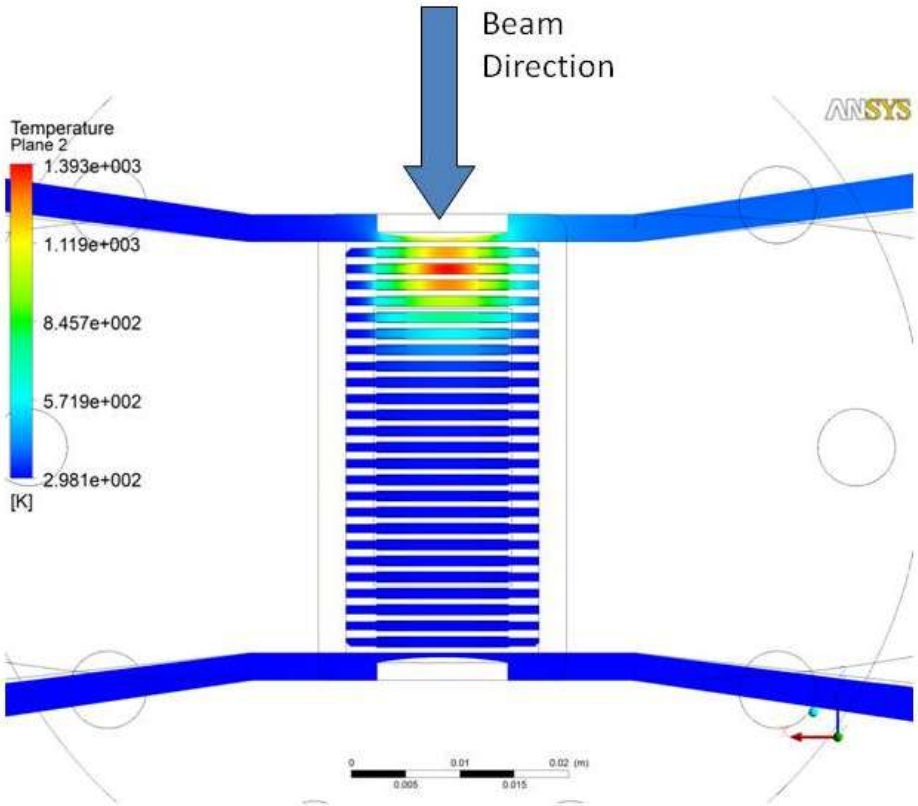


Cooling gas temperature

Cooling gas velocity in each channel

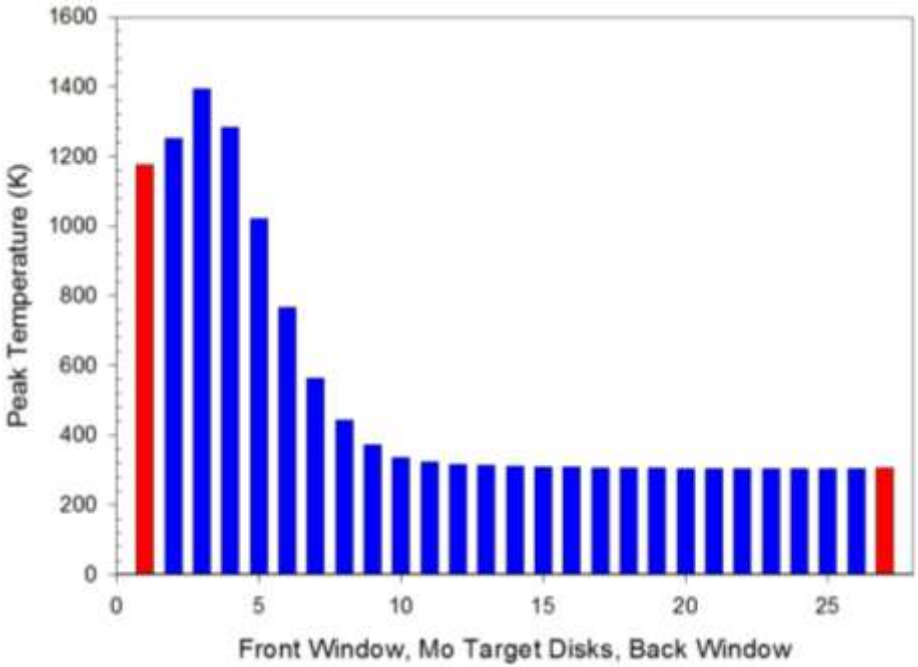


CFD Analysis of the Target Temperature for the Thermal Test

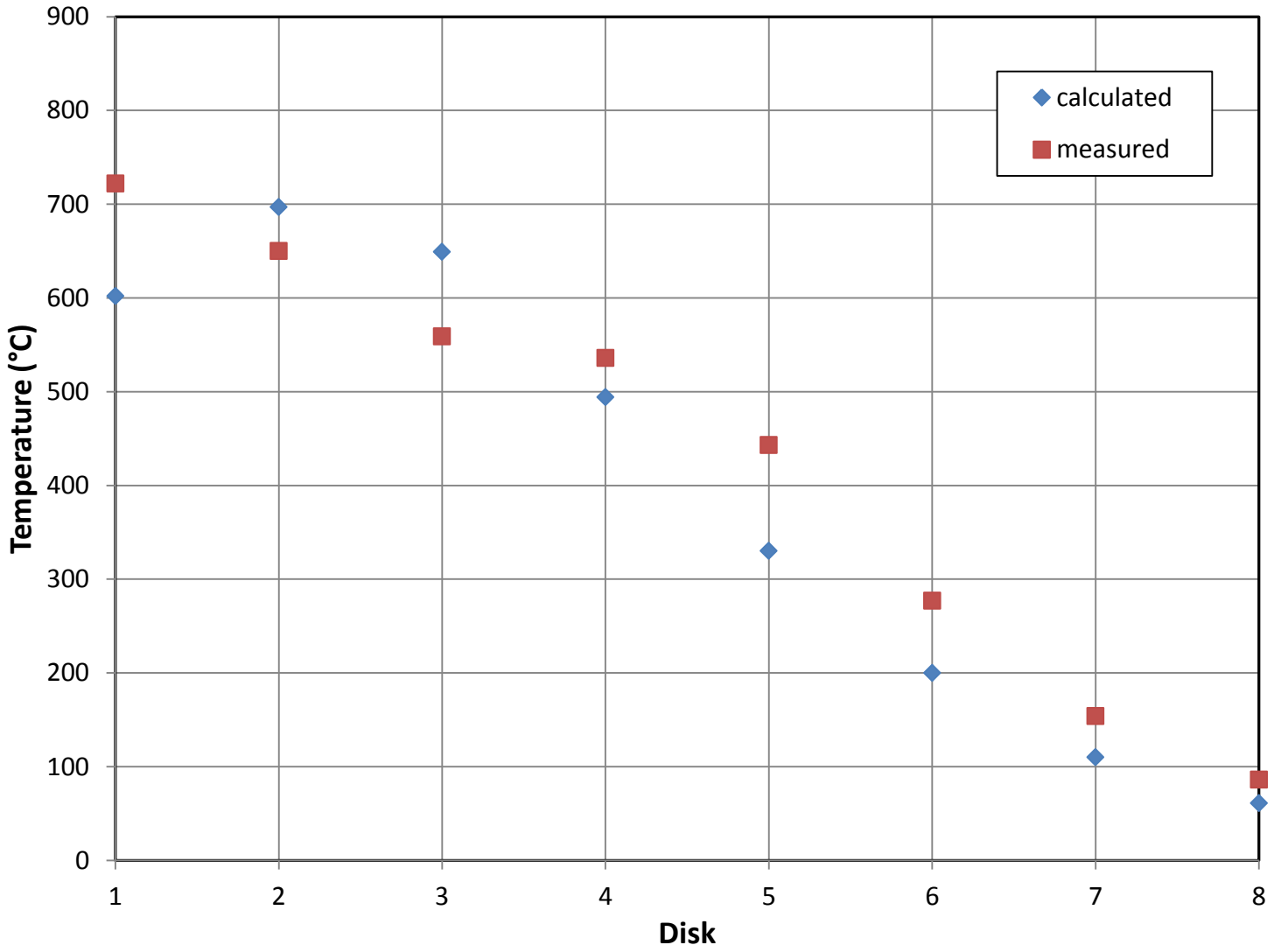


Temperature plot of the target assembly and housing for 15 MeV and 1170 µA (17.6 kW)

Peak temperature of the front window, target assembly, and back window for 15 MeV and 1170 µA (17.6 kW)

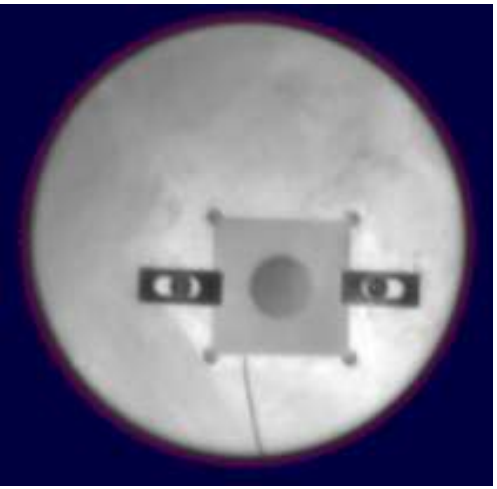


Disk Thermocouple Data
12 kW beam, 270 psi, 25 psi ΔP, 100 g/sec



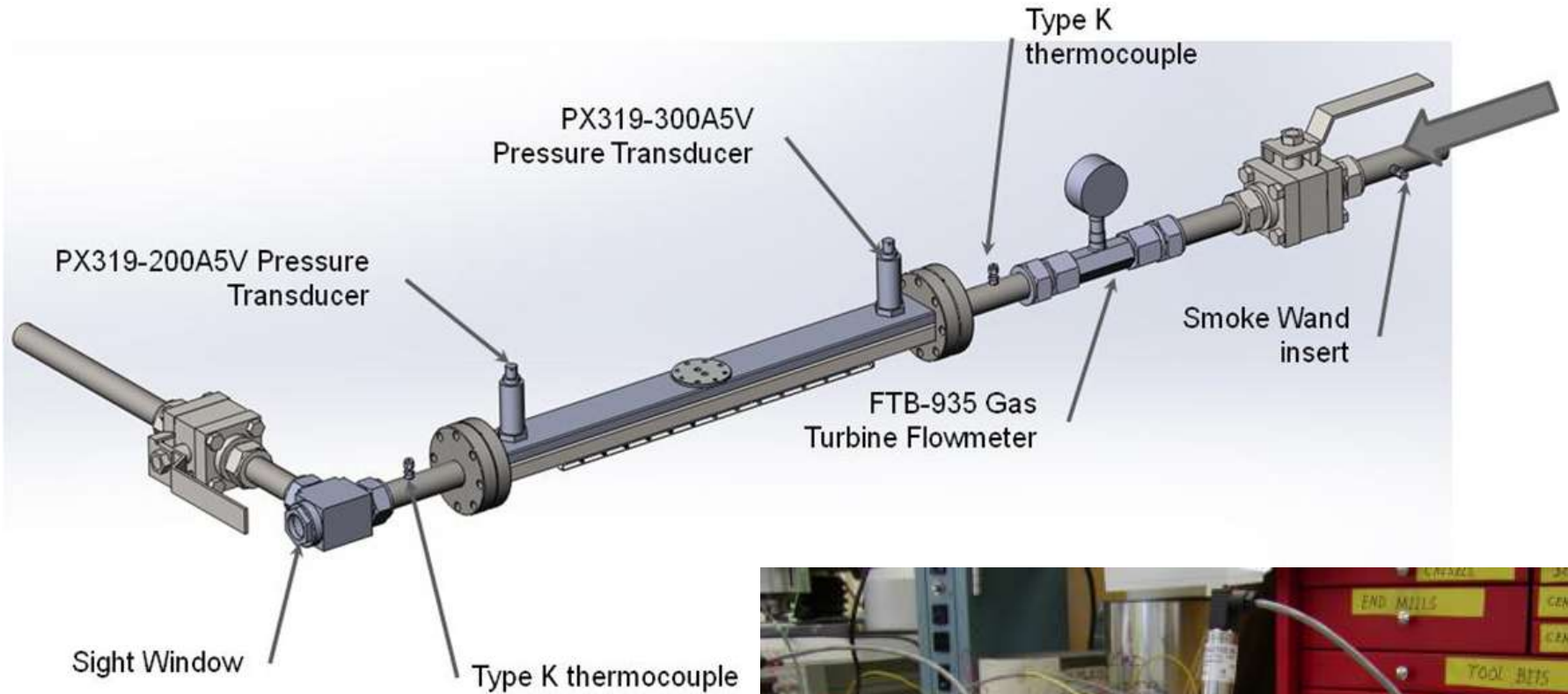
IR Camera for Target Window Temperature Measurement

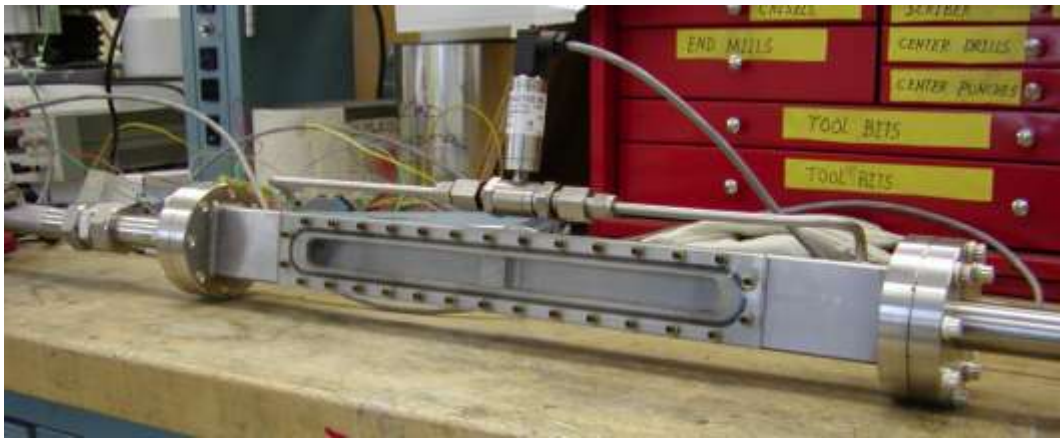
- **The target window is the most highly stressed component of the design.**
- **An infrared (IR) camera system has been developed to monitor the front window temperature during irradiation.**
- **The IR system complements the optical transition radiation (OTR) system used to measure the beam spot size and profile during the irradiation.**



IR image of a test coupon used at LANL to calibrate the camera

Mock up and flow test of the target section using particle image velocimetry (PIV)





Future Work

- Planning to perform a thermal test of the target using the upgraded ANL electron accelerator. Two sided irradiation will be demonstrated during this next thermal test.
- The thermal test will be followed by a production test using enriched ^{100}Mo targets.
- Planning on more production tests over the summer to test multiple batches of enriched ^{100}Mo targets.
- Working with Mevex, the accelerator supplier for the production facility, to install a closed-loop helium cooling system at their facility. This has begun the process of integrating the target cooling system design into the production accelerator system. Planning on a summer thermal test at Mevex to test the system at production relevant heat fluxes.